

98.30-00

A



## PATENT APPLICATION

Assistant Commissioner for Patents  
 Box **Patent Application**  
 Washington, D. C. 20231



Sir:

Enclosed herewith for filing is the following utility patent application.

Applicant(s): **Ted Chongpi Lee, Chin-Yeh Chi, Chinh Q. Le and Arun K. Rai**

Title of application: **METHOD AND APPARATUS FOR NETWORK LOAD-BALANCING**

Pages of specification: **19** (13 + 5 pages of claims and 1 page abstract)

Sheets of drawing: **4**

Executed on: **8/24/00** Attorney Docket No. **Chi 1-1-5-1**

## PATENT APPLICATION FILING FEE CALCULATION

	<u>No. Filed</u>	<u>Less</u>	<u>Rate/Claim</u>	<u>Fee</u>
Total Claims	20	-20	0 x \$18.00	\$ 000.00
Independent Claims	6	- 3	3 x \$78.00	\$ 234.00
Minimum Filing Fee				\$ 690.00
Multiple Dependency Fee (if applicable - \$260.00)				\$ 000.00
Total Filing Fee (Large Entity)				\$ 924.00
50% Reduction for Small Entity (Independent Inventor, Non-profit Corporation, or Small Business Concern) - appropriate verified statement attached				- \$ 00.00
TOTAL FILING FEE DUE				\$ 924.00

Kindly charge the entire and/or any additional filing fee, and fees pursuant to 37 C.F.R. 1.16 and 37 C.F.R. 1.17 during the

pendency of this application, as appropriate, to Lucent Technologies, Inc. deposit account number 12-2325. To facilitate that charge, a duplicate copy of this letter is enclosed herewith.

Also enclosed herewith for filing in connection with the enclosed application are:

       Oath;  
XX        Declaration and Power of Attorney;  
       Disclosure Statement;  
       Letter referencing previously filed disclosure document; number            filed           ;  
       Verified Statement claiming small entity status;  
XX        An assignment of the application to: Lucent Technologies Inc. (with assignment recordation cover sheet);  
       Claim(s) to priority  
                    Serial Number                    Filing date  
       A certified copy of a            patent application or inventor's certificate, filed            and serial no.           , upon which a claim to priority is made;  
XX        Other: Postal Card Receipt

Respectfully submitted,

8/29/00

EJ Wall

Eamon J. Wall, Attorney  
Reg. No. 39,414

Thomason, Moser & Patterson, LLP  
Attorneys At Law  
595 Shrewsbury Avenue, 1<sup>st</sup> Floor  
Shrewsbury, New Jersey 07702

**METHOD AND APPARATUS FOR NETWORK LOAD-BALANCING**TECHNICAL FIELD

The invention relates to the field of communications systems and, more specifically, to an adaptive/iterative load-balancing method suitable for use in network management systems providing automatic route provisioning and/or manual route provisioning.

10                   BACKGROUND OF THE INVENTION

Telecommunication networks and other networks are increasing in both size and complexity. It is anticipated that this trend will continue such that very large telecommunications networks having tens of thousands of nodes will become increasingly commonplace. Unfortunately, as such networks increase in size, the network management function also increases in complexity. This means that critical tasks such as provisioning (allocating resources to form a communications link), restoration, reinstatement and the like, must be completed in a reasonable time using network management tools available to a network manager at a single location.

In a manual provisioning mode, an operator specifies all details of a circuit such as end points, all links, time slots, and all network elements. The manual provisioning mode allows the operator to select a particular circuit providing a communication circuit for DS-1, DS-3, EC-1, OC-3 and other communications services. However, the manual provisioning mode is slow (the operator must select all links manually) and error prone (the operator may make an error in selecting these links).

In an automatic provisioning mode, the operator specifies end points (i.e., start node and end node) and type of circuit needed to provide the desired communication. A network manager system responsively examines all of the spare resources available in the network and selects the optimum path for the

requested circuit. This automatic provisioning mode requires the identification of all spare resources such as channels and communication links from the data base, the constructing of a graphical or other depiction of the spare resources within  
5 computer memory and the execution of a shortest path algorithm to find the optimum route.

Within a telecommunications network comprising many network elements (NEs) or nodes, it is desirable to balance the network traffic such that the network elements or nodes are not  
10 over utilized. Unfortunately, provisioning algorithms do not properly account for system-wide network element loading levels. That is, present provisioning algorithms tend to over utilize some nodes and under utilize other nodes while attempting to provide a "shortest path" for provisioned  
15 circuits.

Therefore, it is seen to be desirable to provide a method for provisioning a circuit in a manner that avoids over utilizing network elements or nodes. Additionally, it is seen to be desirable to adapt automatic provisioning and/or manual  
20 provisioning techniques in a manner that avoids over utilizing network elements or nodes.

#### SUMMARY OF THE INVENTION

The invention comprises a method and apparatus for  
25 provisioning a circuit in a manner that avoids over utilizing or overloading communications links between network elements (NEs) or nodes within a telecommunications or other network.

Specifically, a method according to one embodiment of the invention comprises the step of: iteratively defining a circuit  
30 path between a source node and a destination node in a network comprising a plurality of nodes interconnected by links, where each link has associated with it a respective bandwidth utilization level, and where the links having bandwidth utilization levels exceeding a threshold level are not used to  
35 define the circuit path.

### BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 depicts a high level block diagram of a communications system;

5        FIG. 2 depicts a high level block diagram of a network manager suitable for use in the communications system of FIG. 1;

10        FIG. 3 depicts a graphical representation of a source node, an end node and a plurality of intervening nodes within a network;

FIG. 4 comprises a flow diagram of a method of selecting a load-balanced shortest path according to an embodiment of the invention.

15        To facilitate understanding, identical reference numerals have been used, where possible, to designate identical elements that are common to the figures.

### DETAILED DESCRIPTION OF THE INVENTION

20        The subject invention will be described within the context of a telecommunication system comprising a large number of network elements or nodes interconnected in a mesh topology. However, it will be appreciated by those skilled in the art that the subject invention may be advantageously employed in any communications network in which provisioning of any form of communication may be utilized, such as telecommunication, data communication, streaming media communication and the like. Thus, it is contemplated by the inventors that the subject invention has broad applicability beyond the telecommunication network described herein.

30        Provisioning (manual or automatic) comprises the process of selecting the start and end points (nodes) of a communication path, selecting all the nodes and links connecting the start and end nodes, finding the "best" communication path between the start and end nodes, and  
35        generating the commands to each of the nodes within the "best"

path such that cross-connects within the network cause the path to be formed, thereby enabling traffic flow through the provisioned circuit. It is noted that each link typically comprises a plurality of channels, and that each channel typically has time slots that can be reserved.

The provisioning of a circuit is a network management layer function within the telecommunications management network (TMN) standards, described in more detail in International Telecommunications Union (ITU) standard documents such as recommendation M.3010 and related documents, which are incorporated herein by reference in their entireties. It is noted that the TMN functional layers also include a service management layer which is above, and interacts with, the network management layer. Therefore, in the case of TMN management at the service management layer, the network management layer functions may not be performed manually.

FIG. 1 depicts a high level block diagram of a communications system. Specifically, the communications system 100 of FIG. 1 comprises a database 110, a network manager or controller 120, a plurality of work stations  $130_1$  through  $130_n$  (collectively work stations 130), a communications link 134 and a multi-node communication network 140.

The multi-node communication network 140 comprises a plurality of network elements (NE) denoted as network elements  $NE_1$  through  $NE_x$  (collectively network elements NE). Also depicted is a start-node SN and an end-node EN. As will be discussed in more detail below with respect to FIGS. 3 and 4, the invention operates to determine the shortest path between a source (start) node and a destination (end) node for provisioning a circuit in a manner that adapts to the bandwidth utilization or "loading" placed upon each link connecting the source node, destination node, and intervening nodes. In this manner, the invention operates to insure that each link within the provisioned circuit is operating at a loading level below a threshold value. It is noted that the threshold level may be

adapted (i.e., increased or decreased) in response to, for example, calculated circuit paths being too long (e.g., a calculated circuit path comprising 50% more nodes than a circuit path calculated without respect to link loading conditions).

The multi-node communication network 140 is coupled to the network manager 120 via signal path S3. The network manager or controller 120 is used to manage various network operations such as the routing of communications and other functions. Specifically, in one embodiment, the multi-node communication network 140 comprises a large number of network elements where each communication to be transmitted from a start network element or start-node to an end network element or end-node requires the determination by the network manager 120 of an appropriate communications path.

The database 110 may comprise a standard mass storage device, such as a redundant array of inexpensive devices (RAID) or other known mass storage device cooperating with a data base program such as the Oracle data base provided by Oracle Corporation of Redwood Shores, California. All that is necessary is that the database 110 be able to communicate with the network manager 120 in a manner facilitating the storage and retrieval of information, such as characterization and control information pertaining to the multi-node communication network 140 including loading information regarding the various links interconnecting the nodes in the network. In one embodiment of the invention, the data base 110 stores information pertaining to each node within the multi-node communication network 140 and, more particularly, to the type of links connecting the nodes, the type of channels provided by these links and the loading or bandwidth utilization of the respective links and/or channels. The data base 110 also stores information pertaining to the availability of time slots for the various links and/or channels used to communicate between nodes.

Each of the work stations 130 communicates with the network manager 120 via, for example, a computer network. It will be appreciated by those skilled in the art that more or fewer work stations 130 may be provided.

5 Each of the work stations 130 may comprise, for example, a terminal used by a network operator to request the provisioning of communication circuits between start-nodes and end-nodes in response to, for example, requests for such circuits from network users. The work stations 130 may also comprise  
10 interfaces between network system users and customers and the network manager 120. Within the context of the present invention, the work stations 130 are used to provide information to the network manager or controller 120 indicative of at least the start node and end node of a circuit to be  
15 provisioned, as well as any quality of service (QOS) or other transmission parameters associated with that circuit. Broadly speaking, all that is necessary to practice the present invention is a communication from some entity, such as a work station 130, indicative of the start node and end node of a  
20 circuit to be provisioned.

The network manager 120 and database 110 of the communications system 100 of FIG. 1 are depicted as separate functional entities. However, it will be appreciated by those skilled in the art that the network manager 120 and database  
25 110 may be combined within a single functional entity. Thus, the network manager 120 and database 110 may be operably combined to form a network management apparatus suitable for managing the multi-node communication network 140 according to the present invention.

30 In one embodiment, the network manager 120 comprises, illustratively, an Integrated Transport Management Network Manager (ITM-NM) manufactured by Lucent Technologies, Inc. of Murray Hill, New Jersey. In this embodiment, the network manager 120 implements network management layer functions  
35 according to, for example, the Telecommunications Management



Network (TMN) standards described in the International Telecommunications Union (ITU) recommendation M.3010 and related documents, which are incorporated herein by reference in their entirety. Thus, the network manager 120 is used to  
5 manage all network elements within the communications system 100 of FIG. 1, both individually and as a set of network elements. The network manager 120 can include or be operatively coupled to various element management systems  $EMS_1$  through  $EMS_n$  (collectively the element management systems EMS)  
10 according to the various management layer functions described in the TMN standard.

FIG. 2 depicts a high level block diagram of a network manager or controller suitable for use in the communications system 100 of FIG. 1. Specifically, the exemplary network  
15 manager or controller 120 of FIG. 2 comprises a processor 120-4 as well as memory 120-8 for storing various network management and control programs 120-8P. The processor 120-4 cooperates with conventional support circuitry 120-3 such as power supplies, clock circuits, cache memory and the like as well as  
20 circuits that assist in executing the software routines stored in the memory 120-8. As such, it is contemplated that some of the process steps discussed herein as software processes may be implemented within hardware, for example, as circuitry that cooperates with the processor 120-4 to perform various steps.  
25 The network manager 120 also contains input-output (I/O) circuitry 120-2 that forms an interface between the various functional elements communicating with the network manager 120. For example, in the embodiment of FIG. 1, the network manager 120 communicates with a database 110 via a signal path S1, each  
30 of a plurality of work stations 130 via signal path S2 and the communication network to be managed 140 via signal path S3.

Although the network manager 120 of FIG. 2 is depicted as a general purpose computer that is programmed to perform various network management functions in accordance with the  
35 present invention, the invention can be implemented in hardware

as, for example, an application specific integrated circuit (ASIC). As such, the process steps described herein are intended to be broadly interpreted as being equivalently performed by software, hardware, or a combination thereof.

5 The network manager 120 of the present invention communicates with the various work stations 130 such as those being used by network operators servicing customers requesting specific connections.

FIG. 3 depicts a graphical representation of circuit  
10 comprising a source node, an end node and a plurality of intervening nodes within a network. Specifically, FIG. 3 depicts a network 300 comprising a plurality of nodes denoted as nodes A through R. Circuit paths or links exist between some of the nodes, but not all of the nodes (though each node  
15 is coupled to at least two other nodes). Circuit links are denoted by two letters indicative of the nodes connected by the respective circuit link.

In the network 300 of FIG. 3, a circuit is to be provisioned between a start node (node A) and an end node (node  
20 G). The shortest path between nodes A and G is the path through the following nodes A-H-I-J-G. However, according to the invention, if the bandwidth utilization level or "load" on any of the links connecting nodes A through G has reached or exceeded a preset threshold level, such as 50% bandwidth  
25 utilization level, then another shortest or "next shortest" path is found where the load is found, such that the threshold level is honored. As depicted in FIG. 3, the next shortest path between nodes A and G is the path through nodes A-B-C-D-E-G. It is noted that the first shortest path traverses three  
30 intervening nodes (H, I and J), while the next shortest path traverses four intervening nodes (B, C, D and E). The next shortest path A-B-C-D-E-G is formed by coupling nodes A and B via path AB, nodes B and C via path BC, nodes C and D via path CD, nodes D and E via path DE, and nodes E and G via path EG.

With respect to the load balancing aspects of the invention, the threshold level for determining whether a link between the two nodes is over utilized may be predetermined or user settable. Moreover, the threshold level preferably is  
5 defined with respect to the type of link joining the two nodes. Additionally, the threshold level preferably applies to each of the digital links used to connect the start node, end node and intervening nodes.

It is noted that the threshold level is a measure for a  
10 digital link, not a measure of the aggregate of links between two nodes. That is, the threshold level is applied to the specific digital link between two nodes contemplated to be used within the provisioned circuit. Where multiple links between two nodes exist, alternate links may be used or the multiple  
15 links may have associated with them different threshold levels, depending on the technology used to provide each link. In this manner, the "shortest path" algorithm and threshold level comparison are used in an iterative fashion whereby each link determined to be appropriate according to the shortest path  
20 algorithm is compared to a corresponding threshold level to determine if the link is, in fact, appropriate with respect to the bandwidth utilization level of the link. If the link is over utilized or otherwise inappropriate, then a different link may be selected for use in the shortest path algorithm. In  
25 this manner, those links following an inappropriate or over utilized link do not have to be processed by the shortest path algorithm.

FIG. 4 comprises a flow diagram of a method of selecting a load-balanced shortest path according to an embodiment of the  
30 invention. Specifically, the method 400 of FIG. 4 utilizes existing shortest path algorithms in an iterative fashion such that each link of a proposed shortest path is checked for loading prior to inclusion within a provision circuit.

The method 400 of FIG. 4 is entered at step 402 and  
35 proceeds to step 404, where all links for a shortest path

determination are accepted. That is, at step 404, none of the possible or acceptable links used to provide a circuit path between a source node and a destination node are excluded from consideration by the shortest path algorithm. The method 400  
5 then proceeds to step 406.

At step 406, at least one link of the shortest path between the source node and the destination node is determined using the presently accepted links. In one embodiment of the invention, only a single link (i.e., a next link) extending  
10 from the node connected to a previously processed link is determined. In another embodiment of the invention, a larger portion or an entirety of a "shortest path" between the node connected to the processed link and the end node is determined. In the case of step 406 being executed for the first time to  
15 determine an entire path, the determined shortest path comprises a "ideal" shortest path. This ideal shortest path comprises the shortest path between the start node and the end node based primarily on the topology of the network and excluding any consideration of the bandwidth utilization levels  
20 of the links used to provide such path. The method 400 then proceeds to step 408.

During the process of constructing an acceptable shortest path between the source node and the destination node, a presently calculated "acceptable" path is formed beginning with  
25 the source node and proceeding toward the destination node. During the formation of this path, the last or terminal node of a path so formed comprises the last node of a path connected to the source node via one or more accepted links. It is noted that for each iteration of the method, a single next link  
30 (coupling the terminal node to a next node) and a plurality of next links (coupling the terminal node to a respective plurality of next nodes or an entire group of links necessary to couple the terminal node to the destination node via as many intervening nodes and links as necessary) may be provided.

At step 408, the loading of the first or next link in the calculated shortest path is determined. That is, if step 408 is being executed for the first time, then the loading of the first link in the determined shortest path is determined. The first link comprises a link between the source node and the first node within the determined shortest path. If step 408 has been previously executed, then the next link loading is determined. For example, in the case of step 408 being executed for the second time, the next link comprises the link bridging the node connected to the first link and the next node. The method 400 then proceeds to step 410.

At step 410, a query is made as to whether the loading of the link determined at step 408 is less than or equal to a threshold level, such as 30%, 50%, 70%, 100% or some other value. If the query at step 410 is answered affirmatively, then the method 400 proceeds to step 414. If the query at step 410 is answered negatively, then the method 400 proceeds to step 412.

At step 412, the link having a loading determined at step 408 is rejected for consideration for the circuit being provisioned. The method 400 then proceeds to step 406, where the shortest path between the source node and destination node is determined using accepted links. The second and subsequent executions of step 406 may utilize the links already determined to have loading levels below their respective threshold levels or by recalculating the entire circuit path. Preferably, the method of the present invention is performed by recalculating the shortest path using links that are known to be loaded below their respective threshold levels.

At step 414 the link having a loading level determined at step 408 is accepted for use in the circuit being provisioned. The method 400 then proceeds to step 416, where a query is made as to whether the path is now complete. That is, at step 416, a query is made as to whether the link accepted at step 414 comprises the final link between a penultimate node and the

destination or end node. If the query at step 416 is answered negatively, then the method 400 proceeds to step 408. If the query at step 416 is answered affirmatively, then the method 400 proceeds to step 418.

5       At step 418, a query is made as to whether the path of the circuit defined by the iterative process described above with respect to FIGS. 406 through 416 is too long. For example, if the path completed using the iterative process is greater than 40%, 50%, 60%, 100% or some other percentage (or distance, 10 latency or other metric) longer than an initially determined or "ideal" shortest path (i.e., a shortest path between the source node and destination node determined without regard to loading), then the path may be deemed to be too long. If the query at step 418 is answered affirmatively, then the method 15 400 proceeds to step 420. If the query at step 418 is answered negatively, then the method 400 proceeds to step 422.

At step 420, the threshold levels of one or more of the links are adjusted. That is, assuming that a default threshold level of 50% loading has been used to accept or exclude links 20 for purposes of provisioning a circuit and that the resulting circuit path has been deemed to be too long at step 418. In this instance, the threshold level applied to one or more of the links may be increased (or decreased) to any level up to 100%. The actual increase in threshold level is preferably 25 made by examining the type of links available for use in provisioning a circuit and modifying the threshold levels accordingly. It should be noted that the threshold level for each of the links between intervening nodes need not be the same, and that individual threshold levels, groups of threshold 30 levels, or the entirety of the threshold levels associated with the links interconnecting the intervening nodes may be adjusted. The method 400 then proceeds to step 404. If the query at step 418 is answered negatively, then the method 400 proceeds to step 422 where the circuit is provisioned and 35 tested. The method exits at step 424.

5 An example of threshold level adjustment (per step 420) will now be discussed. Assume that an OC-3 digital link is configured as 3DS/3 links. In this instance, the threshold levels for the link can be one or two DS3s, which equates to a threshold level of 33% and 67%, respectively. If the threshold level is set at 50%, then only one of the three DS-3 links may be deployed to meet the load-balancing threshold. If the threshold level is raised to 75%, then two of the three DS-3s may be deployed. If the threshold level is 100%, then all 10 three DS-3s may be deployed. Similarly, if an OC-3 digital link is configured as two DS-3s and 28 DS-1s, the threshold for DS-3 can be one or two DS-3s, while the threshold for the DS-1 links can be 1 to 28 DS-1s. If the OC-3 digital link is configured for a single DS-3 and 56 DS-1s, then the threshold 15 level for the DS-3 is one (i.e., 100%), while the threshold for the DS-1s may be 1 to 56 DS-1s. If the OC-3 digital link is configured as 84 DS-1s, then the threshold level may be set as 2 to 83 DS-1s, and there is no DS-3 available. In each of these examples, it is noted that the "granularity" of the 20 threshold level is determined with respect to the type of digital link used and the configuration of that digital link. Thus, in determining threshold levels to be used in comparing loading levels at step 410, it is important to understand the type of digital links offered by the network and the 25 configuration of those digital links.

Although various embodiments which incorporate the teachings of the present invention have been shown and described in detail herein, those skilled in the art can readily devise many other varied embodiments that still 30 incorporate these teachings.

## WHAT IS CLAIMED IS:

1. A method, comprising the step of:  
iteratively defining a circuit path between a source node  
5 and a destination node in a network comprising a plurality of  
nodes interconnected by links, where each link has associated  
with it a respective bandwidth utilization level, and where  
links having bandwidth utilization levels exceeding a threshold  
level are not used to define said circuit path.
- 10 2. The method of claim 1, further comprising the steps of:  
determining an ideal shortest path between the source node  
and destination node;  
comparing the ideal shortest path to the iteratively  
15 defined circuit path; and  
in the case of said iteratively determined circuit path  
exceeding said ideal path by a threshold amount, adjusting said  
threshold level and repeating said step of iteratively defining  
said circuit path.
- 20 3. The method of claim 2, wherein said iteratively defined  
circuit path is compared to said ideal circuit path by  
comparing the number of intervening nodes within each  
respective circuit path.
- 25 4. The method of claim 3, wherein said threshold amount  
comprises a predetermined increase in the number of intervening  
nodes.
- 30 5. The method of claim 2, wherein said iteratively defined  
circuit path is compared to said ideal circuit path by  
comparing the latency within each respective circuit path.
- 35 6. The method of claim 2, wherein said iteratively defined  
circuit path is compared to said ideal circuit path by



comparing the number of links within each respective circuit path.

7. A method, comprising the steps of:

5 determining a shortest path between a source node and a destination node, said shortest path comprising a plurality of intervening nodes coupled by respective links;

determining whether a respective bandwidth utilization level for each link within said circuit path is below a  
10 threshold level; and

adapting said circuit path to avoid using links having respective bandwidth utilization levels above said threshold level.

15 8. The method of claim 7, further comprising the step of:

determining whether a circuit path formed using links having respective bandwidth utilization levels below said threshold level exceeds an ideal shortest circuit path by a threshold amount; and

20 in the case of said circuit path exceeding said ideal path, adjusting said threshold levels and recalculating said circuit path.

9. The method of claim 8, wherein said calculated circuit  
25 path is compared to said ideal circuit path in terms of at least one of a number of nodes within said circuit paths, a latency associated with communications within said circuit paths and a number of links within said circuit paths.

30 10. A method, comprising the steps of:

selecting, according to a shortest path algorithm, at least one link within a circuit path between a starting node and a destination node within a network comprising a plurality of nodes;

determining whether each selected link has associated with it a bandwidth utilization level exceeding a threshold level;

rejecting each selected link having associated with it a bandwidth utilization level exceeding said threshold level; and

5 repeating said steps of selecting and determining until a circuit path between said starting node and said destination node has been determined.

11. The method of claim 10, further comprising the step of  
10 increasing said threshold level in response to said determined circuit path exceeding an ideal circuit path by a predetermined amount.

12. The method of claim 11, wherein said predetermined amount  
15 comprises a difference in at least one of the number of nodes within said circuit paths, the latency associated with communications within said circuit paths and the number of links within said circuit paths.

20 13. The method of claim 10, wherein said step of selecting comprises the step of selecting, according to said shortest path algorithm, each link within a circuit path between the last node of a partially formed circuit path and said destination node.

25 14. A method for determining a circuit path between a source node and a destination node in a network comprising a plurality of nodes interconnected by links, said method comprising the steps of:

30 (a) selecting, according to a shortest path algorithm, an available link to a next node within said circuit path;

(b) determining if said selected link has associated with it a bandwidth utilization level below a threshold level;

(c) rejecting said selected link in the case of said respective bandwidth utilization level being below said threshold level; and

(d) repeating steps (a) through (c) until a circuit path  
5 between said starting node and destination node has been determined.

15. The method of claim 14, further comprising the step of:

(e) determining if said circuit path exceeds an ideal  
10 circuit path by a predetermined amount; and in the case of said circuit path exceeding said ideal circuit by said predetermined amount, adjusting said threshold levels and repeating steps (a) through (d).

15 16. The method of claim 15, wherein said predetermined amount comprises a difference in at least one of the number of nodes within said circuit paths, the latency associated with communications within said circuit paths, and the number of links within said circuit paths.

20

17. A computer readable medium storing a software program that, when executed by a computer, causes the computer to perform a method comprising:

iteratively defining a circuit path between a source node  
25 and a destination node in a network comprising a plurality of nodes interconnected by links, where each link has associated with it a respective bandwidth utilization level, and where links having bandwidth utilization levels exceeding a threshold level are not used to define said circuit path.

30

18. The method of claim 17, further comprising the steps of:

determining an ideal shortest path between the source node and destination node;

comparing the ideal shortest path to the iteratively  
35 defined circuit path; and

in the case of said iteratively determined circuit path exceeding said ideal path by a threshold amount, adjusting said threshold level and repeating said step of iteratively defining said circuit path.

5

19. Apparatus, comprising:

a network manager, for determining a circuit path between a source node and a destination node within a network comprising a plurality of nodes; and

10 a data base, for storing a respective bandwidth utilization level for each of a plurality of links interconnecting said nodes;

said network manager determining said circuit path by iteratively selecting appropriate next nodes according to a  
15 shortest path algorithm, determining whether a link communicating with said selected next node has associated with it a bandwidth utilization level exceeding a threshold level, and selecting an alternative next node in the case of said link having associated with it a bandwidth utilization level  
20 exceeding said threshold level.

20. The apparatus of claim 19, wherein:

in the case of a plurality of alternative next nodes having respective links with bandwidth utilization levels above  
25 said threshold level, adjusting said threshold level.

## ABSTRACT

A method and apparatus for determining a circuit path between a source node and a destination node within a network comprising a plurality of nodes by iteratively selecting appropriate next nodes using a shortest path algorithm and accepting or rejecting the selected next node based upon the bandwidth utilization level of the communications link to the next node. In the case of a lack of acceptable communication links or a determined circuit path exceeding an ideal circuit path by a predetermined amount, the threshold levels defining acceptable links are adjusted.

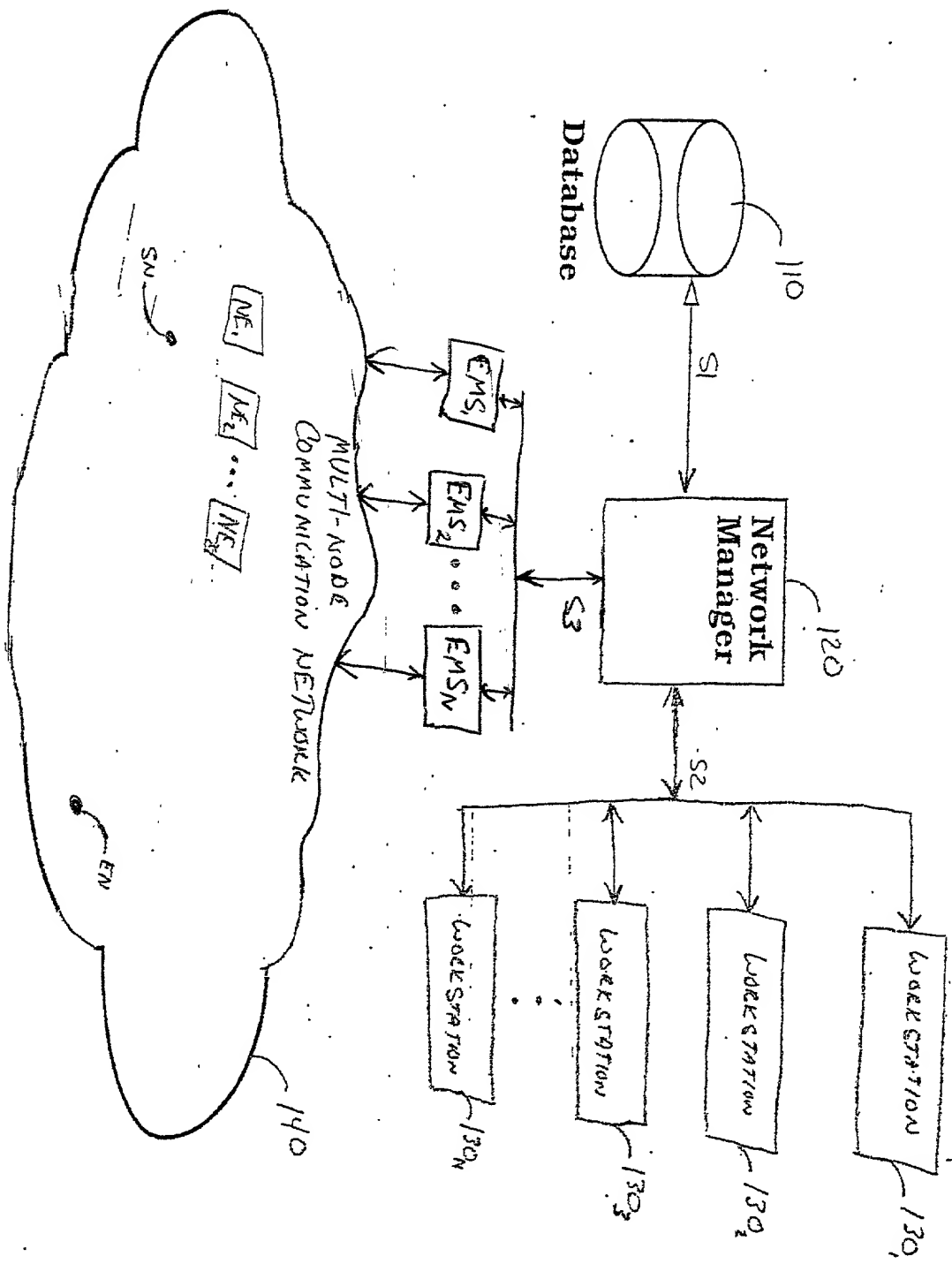


FIG. 1

09650287 082900

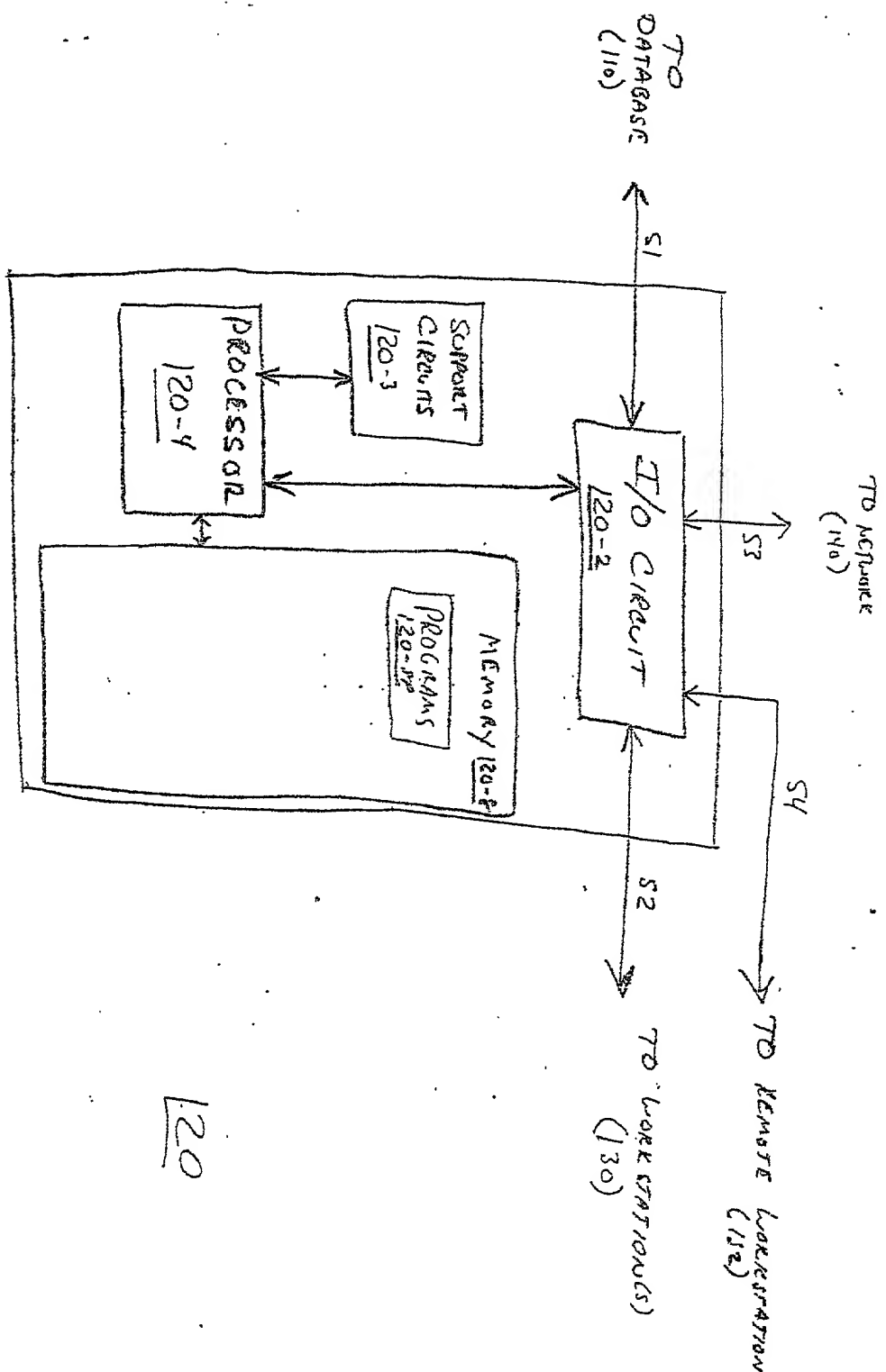
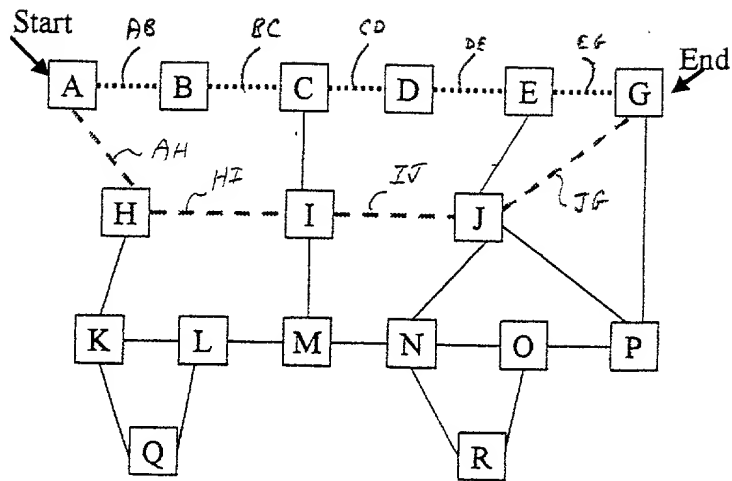


FIG. 2

120

05850227, 082500

1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019 2020 2021 2022 2023 2024 2025 2026 2027 2028 2029 2030 2031 2032 2033 2034 2035 2036 2037 2038 2039 2040 2041 2042 2043 2044 2045 2046 2047 2048 2049 2050 2051 2052 2053 2054 2055 2056 2057 2058 2059 2060 2061 2062 2063 2064 2065 2066 2067 2068 2069 2070 2071 2072 2073 2074 2075 2076 2077 2078 2079 2080 2081 2082 2083 2084 2085 2086 2087 2088 2089 2090 2091 2092 2093 2094 2095 2096 2097 2098 2099 2100 2101 2102 2103 2104 2105 2106 2107 2108 2109 2110 2111 2112 2113 2114 2115 2116 2117 2118 2119 2120 2121 2122 2123 2124 2125 2126 2127 2128 2129 2130 2131 2132 2133 2134 2135 2136 2137 2138 2139 2140 2141 2142 2143 2144 2145 2146 2147 2148 2149 2150 2151 2152 2153 2154 2155 2156 2157 2158 2159 2160 2161 2162 2163 2164 2165 2166 2167 2168 2169 2170 2171 2172 2173 2174 2175 2176 2177 2178 2179 2180 2181 2182 2183 2184 2185 2186 2187 2188 2189 2190 2191 2192 2193 2194 2195 2196 2197 2198 2199 2200 2201 2202 2203 2204 2205 2206 2207 2208 2209 2210 2211 2212 2213 2214 2215 2216 2217 2218 2219 2220 2221 2222 2223 2224 2225 2226 2227 2228 2229 2230 2231 2232 2233 2234 2235 2236 2237 2238 2239 2240 2241 2242 2243 2244 2245 2246 2247 2248 2249 2250 2251 2252 2253 2254 2255 2256 2257 2258 2259 2260 2261 2262 2263 2264 2265 2266 2267 2268 2269 2270 2271 2272 2273 2274 2275 2276 2277 2278 2279 2280 2281 2282 2283 2284 2285 2286 2287 2288 2289 2290 2291 2292 2293 2294 2295 2296 2297 2298 2299 2300 2301 2302 2303 2304 2305 2306 2307 2308 2309 2310 2311 2312 2313 2314 2315 2316 2317 2318 2319 2320 2321 2322 2323 2324 2325 2326 2327 2328 2329 2330 2331 2332 2333 2334 2335 2336 2337 2338 2339 2340 2341 2342 2343 2344 2345 2346 2347 2348 2349 2350 2351 2352 2353 2354 2355 2356 2357 2358 2359 2360 2361 2362 2363 2364 2365 2366 2367 2368 2369 2370 2371 2372 2373 2374 2375 2376 2377 2378 2379 2380 2381 2382 2383 2384 2385 2386 2387 2388 2389 2390 2391 2392 2393 2394 2395 2396 2397 2398 2399 2400 2401 2402 2403 2404 2405 2406 2407 2408 2409 2410 2411 2412 2413 2414 2415 2416 2417 2418 2419 2420 2421 2422 2423 2424 2425 2426 2427 2428 2429 2430 2431 2432 2433 2434 2435 2436 2437 2438 2439 2440 2441 2442 2443 2444 2445 2446 2447 2448 2449 2450 2451 2452 2453 2454 2455 2456 2457 2458 2459 2460 2461 2462 2463 2464 2465 2466 2467 2468 2469 2470 2471 2472 2473 2474 2475 2476 2477 2478 2479 2480 2481 2482 2483 2484 2485 2486 2487 2488 2489 2490 2491 2492 2493 2494 2495 2496 2497 2498 2499 2500 2501 2502 2503 2504 2505 2506 2507 2508 2509 2510 2511 2512 2513 2514 2515 2516 2517 2518 2519 2520 2521 2522 2523 2524 2525 2526 2527 2528 2529 2530 2531 2532 2533 2534 2535 2536 2537 2538 2539 2540 2541 2542 2543 2544 2545 2546 2547 2548 2549 2550 2551 2552 2553 2554 2555 2556 2557 2558 2559 2560 2561 2562 2563 2564 2565 2566 2567 2568 2569 2570 2571 2572 2573 2574 2575 2576 2577 2578 2579 2580 2581 2582 2583 2584 2585 2586 2587 2588 2589 2590 2591 2592 2593 2594 2595 2596 2597 2598 2599 2600 2601 2602 2603 2604 2605 2606 2607 2608 2609 2610 2611 2612 2613 2614 2615 2616 2617 2618 2619 2620 2621 2622 2623 2624 2625 2626 2627 2628 2629 2630 2631 2632 2633 2634 2635 2636 2637 2638 2639 2640 2641 2642 2643 2644 2645 2646 2647 2648 2649 2650 2651 2652 2653 2654 2655 2656 2657 2658 2659 2660 2661 2662 2663 2664 2665 2666 2667 2668 2669 2670 2671 2672 2673 2674 2675 2676 2677 2678 2679 2680 2681 2682 2683 2684 2685 2686 2687 2688 2689 2690 2691 2692 2693 2694 2695 2696 2697 2698 2699 2700 2701 2702 2703 2704 2705 2706 2707 2708 2709 2710 2711 2712 2713 2714 2715 2716 2717 2718 2719 2720 2721 2722 2723 2724 2725 2726 2727 2728 2729 2730 2731 2732 2733 2734 2735 2736 2737 2738 2739 2740 2741 2742 2743 2744 2745 2746 2747 2748 2749 2750 2751 2752 2753 2754 2755 2756 2757 2758 2759 2760 2761 2762 2763 2764 2765 2766 2767 2768 2769 2770 2771 2772 2773 2774 2775 2776 2777 2778 2779 2780 2781 2782 2783 2784 2785 2786 2787 2788 2789 2790 2791 2792 2793 2794 2795 2796 2797 2798 2799 2800 2801 2802 2803 2804 2805 2806 2807 2808 2809 2810 2811 2812



300

FIG. 3



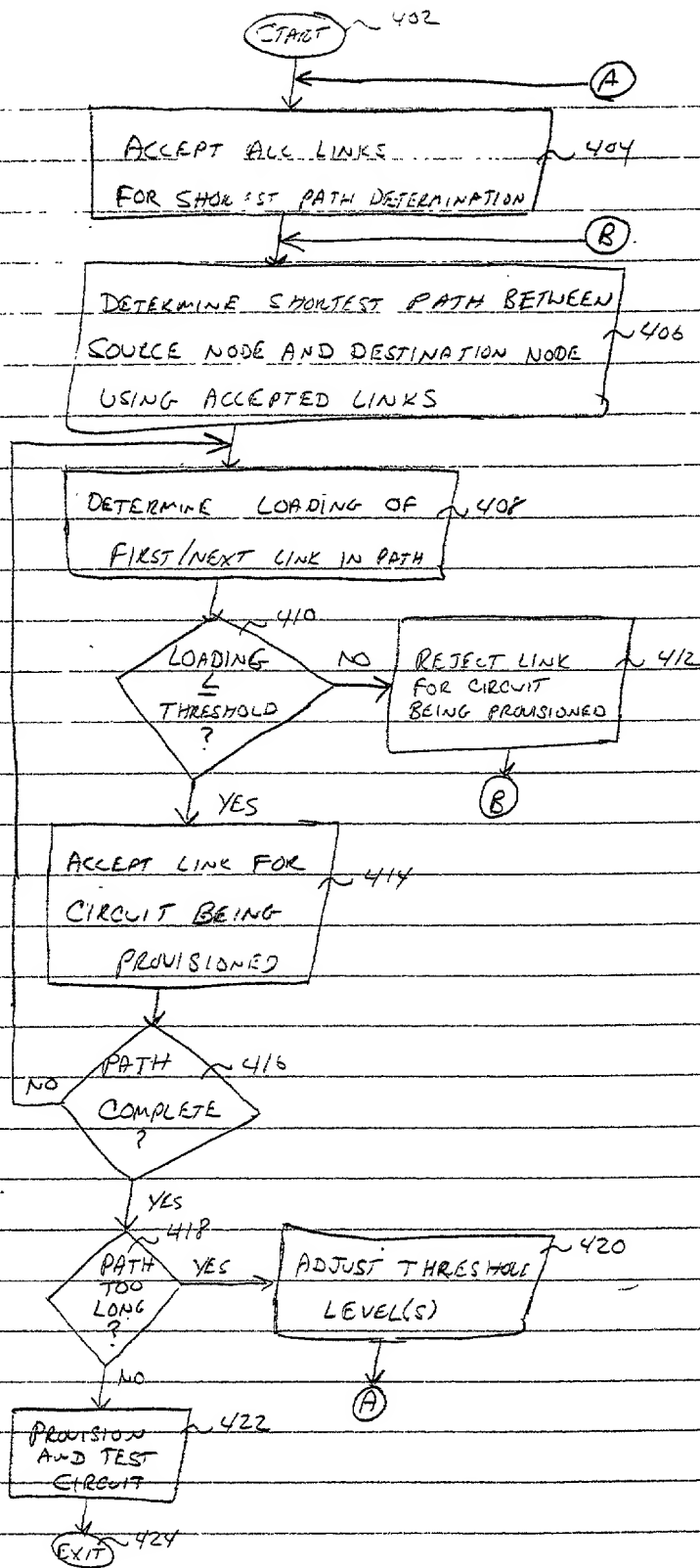


FIG 4

IN THE UNITED STATES  
PATENT AND TRADEMARK OFFICE

Declaration and Power of Attorney

As the below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor of the subject matter which is claimed and for which a patent is sought on the invention entitled **METHOD AND APPARATUS FOR NETWORK LOAD-BALANCING** the specification of which is attached hereto.

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by an amendment, if any, specifically referred to in this oath or declaration.

I acknowledge the duty to disclose all information known to me which is material to patentability as defined in Title 37, Code of Federal Regulations, 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, 119 of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

None

I hereby claim the benefit under Title 35, United States Code, 120 of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, 112, I acknowledge the duty to disclose all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, 1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application:

None

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

I hereby appoint the following attorney(s) with full power of substitution and revocation, to prosecute said application, to make alterations and amendments therein, to receive the patent, and to transact all business in the Patent and Trademark Office connected therewith:

Thomas J. Bean	(Reg. No. 44528)
Lester H. Birnbaum	(Reg. No. 25830)
Richard J. Botos	(Reg. No. 32016)
Jeffery J. Brosemer	(Reg. No. 36096)
Kenneth M. Brown	(Reg. No. 37590)
Donald P. Dinella	(Reg. No. 39961)
Guy Eriksen	(Reg. No. 41736)
Martin I. Finston	(Reg. No. 31613)
William S. Francos	(Reg. No. 38456)
Barry H. Freedman	(Reg. No. 26166)
Julio A. Garceran	(Reg. No. 37138)
Jimmy Goo	(Reg. No. 36528)
Anthony Grillo	(Reg. No. 36535)
Stephen M. Gurey	(Reg. No. 27336)
John M. Harman	(Reg. No. 38173)
Matthew J. Hodulik	(Reg. No. 36164)
Michael B. Johannesen	(Reg. No. 35557)
Mark A. Kurisko	(Reg. No. 38944)
Irena Lager	(Reg. No. 39260)
John B. MacIntyre	(Reg. No. 41170)
Christopher N. Malvone	(Reg. No. 34866)
Scott W. McLellan	(Reg. No. 30776)
Martin G. Meder	(Reg. No. 34674)
John C. Moran	(Reg. No. 30782)
Michael A. Morra	(Reg. No. 28975)
Gregory J. Murgia	(Reg. No. 41209)
Claude R. Narcisse	(Reg. No. 38979)
Joseph J. Opalach	(Reg. No. 36229)
Neil R. Ormos	(Reg. No. 35309)
Eugen E. Pacher	(Reg. No. 29964)
Jack R. Penrod	(Reg. No. 31864)
Gregory C. Ranieri	(Reg. No. 29695)
Scott J. Rittman	(Reg. No. 39010)
Ferdinand M. Romano	(Reg. No. 32752)
Eugene J. Rosenthal	(Reg. No. 36658)
Bruce S. Schneider	(Reg. No. 27949)
Ronald D. Slusky	(Reg. No. 26585)
David L. Smith	(Reg. No. 30592)
Ozer M. N. Teitelbaum	(Reg. No. 36698)
John P. Veschi	(Reg. No. 39058)

David Volejnicek	(Reg. No. 29355)
Charles L. Warren	(Reg. No. 27407)
Jeffrey M. Weinick	(Reg. No. 36304)
Eli Weiss	(Reg. No. 17765)

I hereby appoint the attorney(s) on ATTACHMENT A as associate attorney(s) in the aforementioned application, with full power solely to prosecute said application, to make alterations and amendments therein, to receive the patent, and to transact all business in the Patent and Trademark Office connected with the prosecution of said application. No other powers are granted to such associate attorney(s) and such associate attorney(s) are specifically denied any power of substitution or revocation.

Full name of 1st joint inventor: Ted Chongpi Lee

Inventor's signature Ted C. Lee Date 8-24-2000

Residence: 15 Apple Grove Drive, Holmdel, New Jersey 07733

Citizenship: U.S.A.

Post Office Address: 15 Apple Grove Drive, Holmdel, New Jersey 07733

Full name of 2<sup>nd</sup> joint inventor: Chin-Yeh Chi

Inventor's signature [Signature] Date 8/24/00

Residence: 2 American Way, Holmdel, New Jersey 07733

Citizenship: U.S.A.

Post Office Address: 2 American Way, Holmdel, New Jersey 07733

Full name of 3<sup>rd</sup> joint inventor: Chinh Q. Le

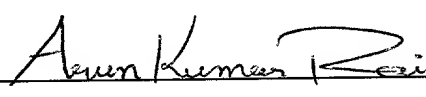
Inventor's signature  Date 08/25/2000

Residence: 6 Pope Road, Bridgewater, New Jersey 08807

Citizenship: Vietnam

Post Office Address: 6 Pope Road, Bridgewater, New Jersey 08807

Full name of 4th joint inventor: Arun K. Rai

Inventor's signature  Date 08/24/00

Residence: 15 Cherrywood Drive, Piscataway, New Jersey 08854

Citizenship: India

Post Office Address: 15 Cherrywood Drive, Piscataway, New Jersey 08854

**ATTACHMENT A**

Attorney Name(s):	Eamon J. Wall	Reg. No.:	39,414
	Raymond R. Moser, Jr.		34,682
	Kin-Wah Tong		39,400
	Wan Yee Cheung		42,410
	Glenn B. Foster		32,676

Telephone calls should be made to EAMON J. WALL at:

Phone No.: 732-530-9404

Fax No.: 732-530-9808

All written communications are to be addressed to:

**THOMASON, MOSER & PATTERSON, LLC**  
**595 Shrewsbury Avenue, 1<sup>st</sup> Floor**  
**Shrewsbury, New Jersey 07702**  
**Attention: Eamon J. Wall**